# Wildland Fire Personnel Transportation Safety Guidebook




Produced by the NWCG Smoke Committee's Training Subcommittee and the University of Idaho VERSION 07-18-14

University of Idaho
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# Transportation Safety Guidebook

## INTRODUCTION

In a wildland fire environment it is your job to maintain situational awareness throughout the duration of the incident, be it wildfire or prescribed fire. This guidebook follows a video on general transportation safety concerns from smoke. Now that you've seen general transportation safety concerns, we'll detail some of the more technical information. Throughout this guidebook you will see references to smoke and fog/superfog/smoke induced fog. The latter is more prevalent in the southeast regions of the US compared to western regions; however it is important to be aware of these factors regardless of your home base.

***This guidebook will address***

- Smoke concerns for firefighters and support personnel
- Smoke concerns for fire managers
    - All Managers
    - Prescribed fire managers
    - Tools for differing regions of the US

## SMOKE CONCERNS FOR FIREFIGHTERS AND SUPPORT PERSONNEL

During an incident it is important to be aware of the inherent dangers of working in low visibility conditions. *It is likely you are the one driving and working in closest proximity to the smoke.*

- All personnel should be aware of low points and other areas where smoke is likely to pool. Report areas of impaired visibility.
- Those driving must remain aware of any reduction in visibility and drop down to a safe speed for the conditions.
- Those patrolling and/or setting up warning signs, especially along busy highways, must understand the hazardous working conditions and how to maintain their own safety, day and night. Remember, visibility of other drivers may be reduced; seeing vehicles and those working outside of vehicles along the roadways may be difficult.
- Everyone involved in implementing a prescribed burn or responding to a wildfire should clearly understand the contingency plan and their specific responsibilities if smoke impacts a roadway. If vehicles are involved in accidents, know what actions are to be taken and who has the responsibilities, especially with any communications that occur.

***Dangerous conditions are most likely to occur when:***
Anytime there is a fire there is the possibility that smoke may drift down a drainage, be transported a distance then settle, or drift directly onto a transportation route. This can occur both on small and large incidents when emissions are being produced or held near the ground by an inversion. But they can also be made worse by certain weather conditions; the fine particles suspended in smoke serve as catalyst and can accelerate fog formation. When there is an exceptional amount of smoke particles and water vapor in the air, the water vapor condenses and thereby can reduce visibility to less than 10 ft. creating a Super-fog or Whiteout Event.

***Discussion Topic***
Have you encountered reduced visibility on the roadway recently? What strategies worked well, which ones did not?

## ALL MANAGERS

To be effective, mitigation plans need to be pro-active and rapidly deployable in a matter of minutes. When it is necessary to close a road because of dangerously reduced visibility, implementation needs to be instantaneous. When conditions have improved, or there is no longer potential hazard, traffic flow should be resumed. When developing mitigating measures continually evaluate:

> **Landscape features and proximity**: Become familiar with the characteristics of the local Air-shed. US air-sheds have been identified for the occurrence of natural fog, frequency of inversions and normal visibility ranges (see the ' Tools for Decision Support' section). All of this information assists wildland fire personnel with situational awareness when responding to wildfires or prescribed fires with roadways within 10 miles. This proximity is a watch out situation. It becomes very critical when roadways are within 3 miles. This necessitates repeated transportation corridor assessments; these should be conducted at critical points or more frequently if weather thresholds are close.
>
> **Fuels:**The presence and availability of large fuels, organic soils or deep duff increases the potential for heavy smoke and smoke induced fog. Smoldering combustion, and to a lesser degree flaming combustion, can overload and saturate nearby air making driving conditions on nearby roadways unsafe. When these conditions are present, plans, including signage and road closures, should be in place ready to mitigate this hazard. Roadways need to be closed well before visibility drops below acceptable safe standards.

***PLANNING & COMMUNICATING for INCIDENT MITIGATION***

Waiting until the smoke and smoke-fog related hazard occurs, and then coordinating with the appropriate agencies/personnel, is too late. Well in advance of the burn or as the wildfire organization ramps up, plan for and carry-out the coordination with other federal, state, and/or local agencies to develop plans for addressing safe traffic flow through areas that can be affected by smoke from the fire. A detailed contingency plan should specify contacts, responsibilities, and the appropriate actions to take before, during, and after a low visibility smoke-related hazard occurs.

A key complication is dealing with the jurisdictional responsibilities associated with managing traffic on highways. Agencies such as State Highway Departments of Transportation must be involved in the location and wording of signs (especially electronic signs) posted to warn motorists of the hazard. State law enforcement or county/local law enforcement as well as Transportation Departments are usually necessary for closing roads or managing traffic flow on highways.

Determine who will be responsible for moving warning signs or posting additional sings to warn motorists. Also determine whether vehicles with emergency warning lights will be on-site.

Getting notices out to news networks (TV and radio) early enough to warn motorists is helpful. Consider public service announcement asking people to use an alternative route for a given time period.

***THE CONTINGENCY PLAN (or "THERE'S SMOKE ON THE ROAD, NOW WHAT?")***

Contingency planning is critical to all wildland fire operations. There are more than enough examples of smoke related problems with burns or wildfires across the country to understand the critical need for good contingency planning. All burn planners or wildfire personnel, regardless of agency,should carefully consider and plan for contingencies to cover smoke related problems.

Even with the best planning, we must remember that conditions can change rapidly, requiring adjustments to our operations. There may be areas where keeping smoke off roadways is difficult to highly unlikely (areas of high road densities, etc). If ignition is delayed and active burning and heavy smoldering occurs with smoke crossing a highway within the nighttime hours, are plans in place to respond? If smoke impacts roadways in areas not planned for, what resources and personnel are needed to respond adequately and safely? In areas prone to smoke induced fog predicting fog is very difficult. If the burn boss or wildfire personnel do not expect fog based on the weather forecast and fog does occur, are plans in place to respond to this change?

One mechanism to alert personnel that contingency implementation may be necessary is by evaluating smoke dispersion conditions, including the potential for smoke-induced fog. This is especially important when there is flaming or smoldering combustion taking place from sunset to sunrise. For more on this topic, see the "Tools for Decision Support" section.



***Discussion Topic***

Who is your primary point of contact if a roadway needs to be closed?

## MANAGERS, PRESCRIBED FIRE

Prescribed fire managers should annually work with local law enforcement (appropriate to your area/state) early in the season to discuss mitigating smoke impacts transportation routes. Have a plan in place to take necessary steps (patrol, pilot cars, road closures) if smoke becomes an issue. Add these contacts to the burn notification section of burn plans and then provide periodic updates throughout the burn season. Know who will do what/when before the need arises.

Using the Minimum Acceptable Visibility (MAV) methodology (Appendix A) may be an appropriate part of implementing a contingency plan. Burn planners should coordinate using MAV with the appropriate law enforcement agency.

### *Actions to Take During Burn Planning*

When planning a prescribed burn, the first priority is protecting public and firefighter safety. A key to protecting people's safety is to avoid putting smoke on a highway, day or night. As part of the burn plan, consider the following in evaluating nighttime smoke dispersion and necessary measures to put into place:

1. Are ignition activities, active burning, or smoldering anticipated during the night, including the 1 hour prior to sunset and 1-hour after sunrise"?
2. Are smoke sensitive sites, especially highways, "down-drainage" from the burn and within a distance that smoke can "flow" to during the night (2-10+ miles)?
3. Is the burn planned to occur when the potential for fog is high (winter and early spring)
4. Does the burn unit contain pockets of heavy fuels (hurricane damage, fallen beetle-killed timber) that could burn and smolder for long periods?
5. Is there a heavy duff layer or organic soils which could smolder for long periods if ignited?
6. Are there areas where slope or topography could cause smoke to collect and create problems?
7. Is open water within or adjacent to the burn (streams, rivers, lakes, ponds or canals)?
8. Are openings (fields or power lines) next to the burn that could funnel smoke toward a highway or other smoke sensitive area?
9. Is the burn unit large with few options to effectively stop the burn if things don't go as planned?
10. What is the potential for local weather phenomenon to affect the burn?
11. Does the burn plan contain appropriate contact information and contingencies for situations where smoke crosses highways, day or night?
12. Do you anticipate a road visibility problem? If so, ask for assistance of appropriate jurisdictional authorities (Department of Transportation (DOT), Sheriff Office, State Highway Patrol) several days before planned burn day.
13. Is the burn window long enough to complete firing the unit and for spreading? Is it long enough for flaming fronts and residual in-place burning cease and the smoke to adequately disperse?

## TOOLS FOR DECISION SUPPORT

*Maintaining situational awareness keeps us alert to the potential of when there should be no driving on nearby roadways unless mitigation measures are in place to react to zero visibility*

The portions of this section dealing with smoke combining with fog address situations more prevalent in the eastern US, but they have applicability to the western US too. Certain conditions can lead to smoke & fog events anywhere in the US. Factors such as terrain, stability, and inversions, in addition to Temperature, relative humidity, wind speed, and cloud cover impact smoke dispersion. Personnel may also be transferred to different regions of the U.S. to address large incidents. For these reasons it is important that all personnel be aware of these tools, even if they are applied more frequently in specific regions.

Wildland fires increase the surrounding air's moisture especially at the surface in low lying areas. Within the fire's proximity air moisture levels can be 10 to 50 times greater than what is found in normal fog as this moisture is generated during the combustion of forest fuels. This abnormally high water content can occur for several hours following the passage of a flaming wildfire or prescribed fire. When the air's augmented high moisture content from the fire combines with favorable weather elements the fine suspended particles in the smoke serve as the triggering mechanism for 'smoke induced' fog. Weather elements include:

1) Temperature: As the air temperature cools below 70°F and gets closer to the dew point temperature, moisture in the air can condense into fog. This usually occurs within 4 degrees or less of the dew point temperature.

2) Relative Humidity: For fog to form there must be adequate air moisture. Relative humidity above 70% can bind to smoke particles forming fog.

3) Wind Speed: Low wind speeds, 4 mph or less, provide calm conditions where smoke settles, collects, and can facilitate fog formation.

4) Cloud Cover: Cloud Cover of 60 % or less facilitates rapid cooling which contributes to fog formation. On nights with clear skies and light winds, air temperature can drop rapidly, 2 to 3 degrees Fahrenheit per hour. The moisture in the air at night can condense when the rapidly cooling air temperature approaches the dew point temperature (relative humidity of 100%).

The National Weather Service forecast products contain information that can provide key intelligence on four key weather elements (above) and their influence on natural fog occurrence, smoke dispersion and smoke induced fog. These are derived from a gridded modeled weather and can be placed in various products (Fire Weather Point Matrix, Weather Activity Planner and Hourly Graphical Weather) that have been recently developed. When wildland fire smoke and these weather elements combine, roadway visibility becomes very poor and driving extremely hazardous. It is important to be aware of these weather elements and their critical thresholds as conditions can change quickly.

There are also indices or a classification that can assist in gauging the impact of these weather elements and how they influence smoke dispersion. These are:

1) Turner Stability Class**(Appendix B)**
2) Atmospheric Dispersion Index **(Appendix C)**
3) Low Visibility Occurrence Risk Index **(Appendix D)**
4) Fog Potential***(Appendix E)**

These tools have their respective critical threshold levels:

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Note that the critical values stated herein by subject matter experts are intended to be evaluated together. Using any one index singularly as a basis for decision making may not be appropriate. For detailed information on the strengths and weaknesses of each index, see the literature references in the corresponding appendix sections.

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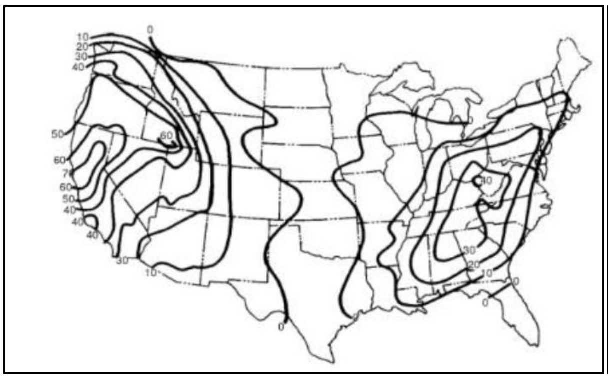
1) Turner Stability ≥ 5, 6, or 7 (E, F, or G)
2) Atmospheric Dispersion Index ≤ 10 with values ≤ 6 very critical.
3) Low Visibility Occurrence Risk Index ≥ 7 with 10 being the highest
4) Superfog Potential Index is currently being developed and will be incorporated into the NWS Fire Weather Point Forecast matrix first.

| **Variables to evaluate for Smoke Induced Fog on transportation corridors from sunset to sunrise when prescribed or wild fires have persisting smoke production** | **Do the variables reach critical threshold values?** | | **Critical Overlap** |
|---|---|---|---|
| | **Present (x)** | **Hours present** | **Common Hours** |
| **SURFACE TEMP ≤ 70° F** | | | |
| **RH (≥ 70% / critical > 90%)** | | | |
| **SURFACE WIND SPEED (<7 mph critical ≤ 4mph)** | | | |
| **CLOUD COVER (<60%, critical <40%)** | | | |
| **TURNER STABILITY (E,F, or G)** | | | |
| **ATMOSPHERIC DISPERSION (<10, critical ≤ 6)*** | | | |
| **LOW VIS. OCCURRENCE RISK (≥7, critical ≥ 9)** | | | |
| ***Transportation Corridor Distance in miles from smoke source*** **(mountain topography supports greater surface smoke transport distances)** | **0-3** | **5-7** | **10+** |

*In a study to develop a risk index for reduced visibility on highways [1] it was noted that "the risk of smoke and fog reports at an accident sites in Florida increased when RH ≥80%, especially for very low dispersion index (DI) values. Risk was highest for saturated air conditions, (RH >97% and DI = 1 or 2), however, risk remained high for saturated RH with DI values up to 12". Under saturated air conditions, RH >97% and DI ≤ 6, ten to fourteen percent of accidents reports examined mentions fog or fog in combination with smoke within the report.

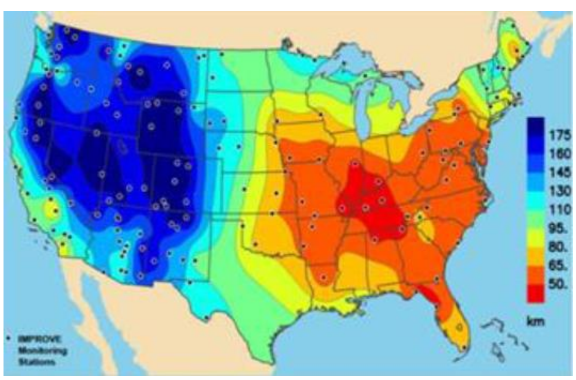
The fire weather information in the above table is available from the National Weather Service (NWS). The local user community must notify the NWS Fire Weather Focal Point that the information is to be part of the local fire weather program. This information can be made available in the Fire Weather Point Forecast Matrix (PFW), Area Fire Weather Forecast Matrix (AFW), the Hourly Weather Graph, and Weather Activity Planner. Each local NWS weather forecasting office would need to develop the local weather grids for the respective indices and place them in the respective products.

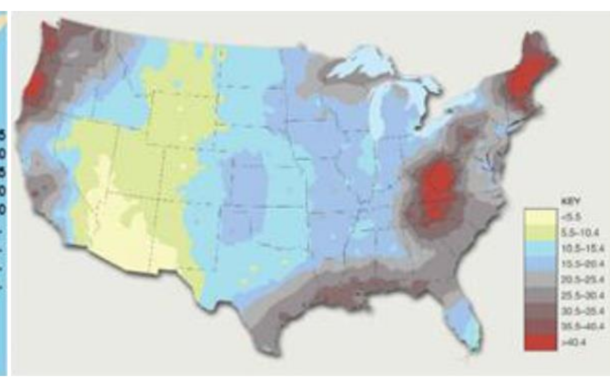
## *It is always beneficial to know your airshed*




***Top Left:*** *The number of days with forecasted high pollution potential can vary by regions, as seen in this chart of the United States (1960-1964) (Adapted from Holzworth).*

***Top Right:*** The country is divided into significant air-sheds due to the work performed on the Ventilation Climate Information System (VCIS). Here we see Regional Airshed boundaries for the contiguous US and Alaska (*from: 'Assessing Values of AQ & Visibility at Risk From Wildland Fires'*).More information on VCIS can be reviewed at: http://plone.airfire.org/wfdss-aq/help/ vcis#section-1



Visible range and the frequency of dense fog vary by geographic location.

***Bottom Left:*** This map illustrates the average visible range, in kilometers, across the continental US.Large differences exist in visibility between the eastern andwestern United States, with westernvisibility generally being substantially better than easternconditions. Climatic factors such as higher relative humidity andthe greater density, quantity, and mix of emissions in the East are some of the reasons for this difference.

***Bottom Right***: The average number of days per year an area experiences dense fog also changes with geographic region. For more information visit: http://www.nature.nps.gov/air/monitoring/vismonresults.cfm

***Discussion Topic***
What decision support tools or indices are commonly available in your area? Do you work with an individual or rely on a specific department or agency for the information?



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# Appendix A - Minimum Acceptable Visibility (MAV)

### Minimum Acceptable Visibility (MAV) methodology– (Adapted from CA Highway Patrol, 1984)

The steps required to meet highway visibility safety standards are based on smoke density or sight distance along the travel route and then apply a "reduced visibility braking factor" similar to that required for braking in a foggy environment. This minimum acceptable visibility adjustment factor (AF) is 1.75 (California Highway Patrol, 1984). It is multiplied by the normal braking distance required for a vehicle to stop if traveling at a posted speed limit, given dry and clear (ideal) conditions.

Minimum Acceptable Visibility (MAV) is calculated using the **California Highway Patrol formula**:

**MAV = (EB + FB) (AF)** where

| MAV = minimum acceptable visibility at posted speed EB = Eye-to-brain reaction distance under clear conditions FB = Foot-to-brake reaction distance under clear conditions EB + FB = Total distance traveled while braking under ideal conditions AF = 1.75 (constant) **Posted Speed Limit** | **(EB + FB) x (AF)** | **MAV (ft.)** | **MAV @ night or Simple Divided Rd** |
|---|---|---|---|
| 10 | (10.5 + 6.6) x 1.75 | 28 | 56 |
| 15 | (16.0 + 12.5) x 1.75 | 50 | 100 |
| 20 | (21.5 + 22.2 ) x 1.75 | 76 | 152 |
| 25 | (27.0 + 34.7) x 1.75 | 108 | 216 |
| 30 | (32.5 + 50.0) x 1.75 | 144 | 288 |
| 35 | (38.0 + 68.0) x 1.75 | 185 | 370 |
| 40 | (43.5 + 88.9) x 1.75 | 232 | 464 |
| 45 | (49.0 + 112.5) x 1.75 | 283 | 566 |
| 50 | (54.5 + 138.9) x 1.75 | 338 | 676 |
| 55 | (60.0 + 168.0) x 1.75 | 399 | 798 |
| 60 | (65.5 + 200.0) x 1.75 | 465 | 930 |
| 65 | (71.0 + 234.7) x 1.75 | 535 | 1070 |

**The MAV should be doubled if smoke is present along the road at night**. The MAV should also be doubled when the road is a simple divided highway, because there is an increased chance of head-on collisions. The visibility adjustment factor does not take into account a head-on encounter of two vehicles traveling in opposite directions.

**Mitigating Reduced Visibility Situations**

Take the following steps to mitigate for reduced visibility when a paved road is affected by smoke. These actions are presented in order of decreasing visibility; implementation of step 3, for example, means that steps 1 and 2 have been taken.

1. Post "Smoke on Road" signs when visibility is twice the MAV value or less: for example, the sight distance is reduced to 220 ft and the posted rate of speed is 25 mph (MAV = 108 ft).
2. Reduce posted speed limit when visibility is at MAV value, or less: for example, sight distance is 110 ft and the posted speed is 45 mph (MAV =283 ft); therefore, the posted speed limit must be reduced, to 25 mph or less.
3. Unless a lead car is on scene, stop traffic by closing the road to travel when the ratio of actual visibility to MAV is 1/2 or less: for example, the sight distance is 50 ft and the posted speed limit is 25 mph (MAV = 108 ft).
4. When the ratio of actual visibility to MAV is less than 1/5, close the road to all but administrative use.

# Appendix B – Turner Stability Classification

## APPENDIX B. PASQUILL – GIFFORD - TURNER STABILITY CLASSIFICATION SYSTEM OR SIMPLY TURNER STABILITY (TS)

The tendency of the atmosphere to tolerate, resist, or enhance vertical motion is termed **stability**. Stability is related to the change of temperature with height (the lapse rate) (Figure 1) driven by the boundary layer energy budget, and wind speed together with surface characteristics (roughness and/or vegetation).

The atmosphere stability is by far the most important parameter affecting dilution of a pollutant. The more unstable the atmosphere is, the greater the dilution of pollutants. An unstable atmosphere enhances turbulence, whereas a stable atmosphere inhibits mechanical turbulence. A neutral atmosphere neither enhances nor inhibits mechanical turbulence.

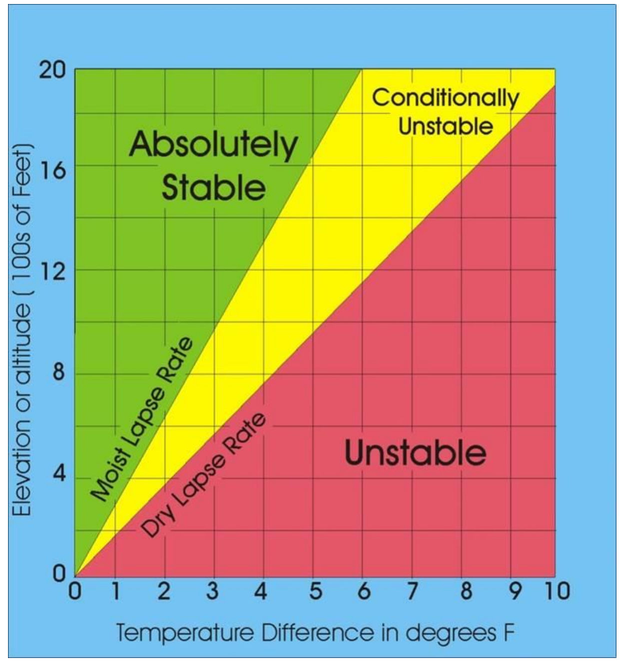
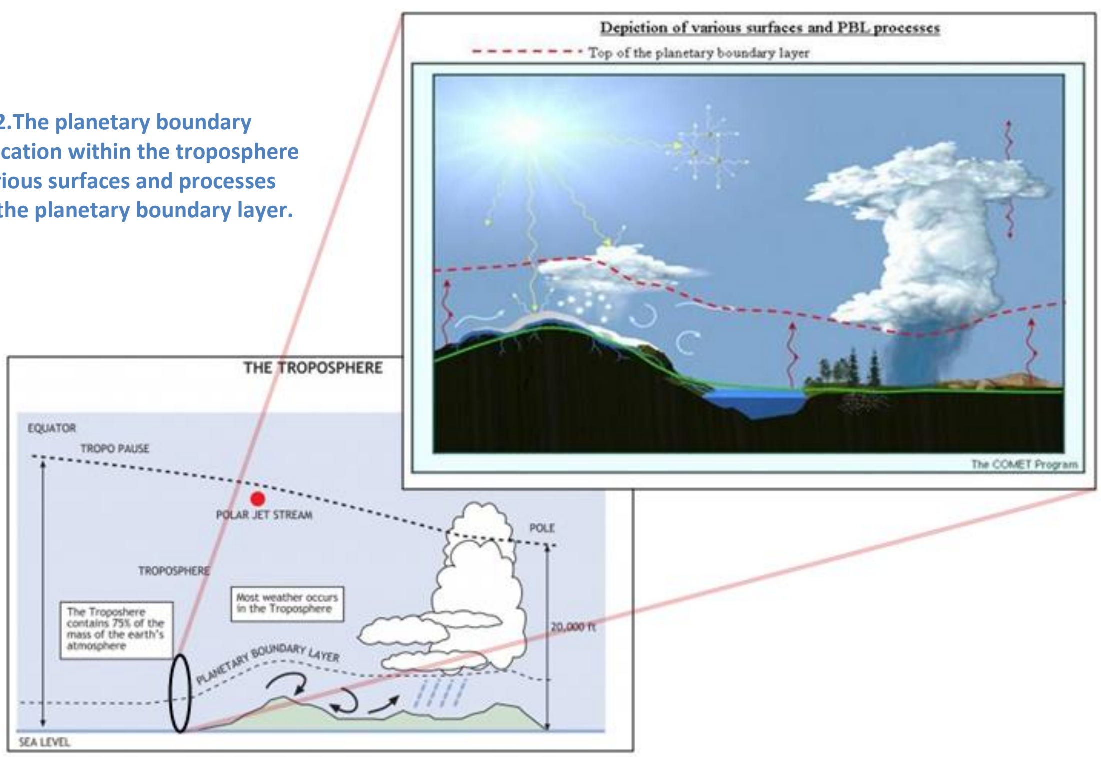



Figure 1 Stability differences with changing temperature and height.

Turner Stability (TS) depicts what is taking place in **the Planetary Boundary Layer (PBL)**(Figure 2). It takes into account flow velocity, temperature, moisture, etc., in the lowest part of the atmosphere whose behavior is directly influenced by its contact with the surface features or vegetation. TS paints a picture of rapid fluctuations (turbulence) and vertical mixing at the surface and how smoke can disperse from its point of origin.  In smoke dispersion, stability relates to turbulence both horizontally and vertically. Turbulence can be depicted in simple way by using TS.

Figure 2.The planetary boundary layer location within the troposphere and various surfaces and processes within the planetary boundary layer.



# Appendix B – Turner Stability Classification

- ***The atmosphere stability is one of the most important parameter affecting dilution of a pollutant.***
- ***Turner Stability takes into account factors in the lowest part of the atmosphere, directly influenced by its contact with the surface features or vegetation.***
- ***In smoke dispersion, stability relates to turbulence both horizontally and vertically. Turbulence can be determined in simple way by using TS.***

Turner Stability classes are defined for different meteorological conditions, characterized by wind speed and solar radiation during the day and cloud cover during the night (Figure 4). It includes seven stability classes (Figure 3):

Stability Classes influence turbulence which in turn facilitates mixing of ambient air with the smoke plume to dilute and/or disperse the plume. Turbulence influences mixing through mechanical, shearing or buoyant means.

Note that Class D applies to heavily overcast skies, at any wind speed day or night.

Historical stability class data, known as the Stability Array (STAR) data, for sites within the USA can be purchased from the National Climatic Data Center (NCDC).

| Classes | | Interpretation |
|---|---|---|
| 1 | A | Very Unstable |
| 2 | B | Moderately Unstable |
| 3 | C | Slightly Unstable |
| 4 | D | Neutral |
| 5 | E | Stable |
| 6 | F | Very stable |
| 7 | G | Extremely Stable |

Figure 3 Seven stability classes A-G.

| Wind speed (m/s) | Wind Speed (mph)* | DAY Incoming solar radiation | | | NIGHT | |
|---|---|---|---|---|---|---|
| | | Strong | Moderate | Slight | > 4/8 cloud | < 3/8 cloud |
| < 2 | 5 | A | A - B | B | E | F |
| 2 - 3 | 5-7 | A - B | B | C | E | F |
| 3 - 5 | 7-11 | B | B - C | C | D | E |
| 5 - 6 | 11-13 | C | C - D | D | D | D |
| > 6 | 13 | C | D | D | D | D |

Figure 4.Weather elements corresponding to different Turner Stability classes. Wind speeds are rounded to the nearest value

**Background:** *The Pasquill-Turner Stability Classes are based on the estimation scheme first developed by Pasquill (1961, 1974), modified by Gifford (1962), and then reformulated for computer application by Turner (1961, 1964).*

# Appendix B – Turner Stability Classification

The amount of turbulence in the ambient atmosphere has a major effect on the dispersion of air pollution plumes because turbulence increases the entrainment and mixing of unpolluted air into the plume thereby acting to reduce the concentration of pollutants in the plume (i.e., enhances the plume dispersion). It is therefore important to categorize stability and the potential for atmospheric turbulence present at any given time. To attain a sustained TS class of A, B, C, or D from sunset to sunrise for southern air-sheds is not a predominant occurrence. However, a sustained TS Class D is a prime opportunity for conducting nighttime prescribed burning. This class means the smoke plume can rise to a height above the ground where the plume temperature equals that of the surrounding air. The plume is elevated off the ground and maintains this level where it is in equilibrium as it is horizontally transported downwind.

For as long as class D extends through nighttime hours, the burning window can be extended. <u>During the flaming phase, convective heating will keep smoke above the surface while extensive smoldering can reduce surface visibility. However, class D and its associated surface winds should be disruptive to prevent superfog events.</u> . Prescribed burns need to be concluded well before stability classes of E, F, or G set in. These classes are usually associated with inversions. If smoke becomes trapped under an inversion with stagnant, calm or low wind speeds, poor air quality and visibility results. It also creates opportunities for superfog events. Local TS climatology can provide historical insight as to when and where favorable conditions for dispersion occur.

**Figure 5 Effects of topography and air temperature on a layer of air in a neutral atmosphere. Image courtesy of Craig Sanders, NWS, Duluth MN.**

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# Appendix C – Atmospheric Dispersion Index (ADI)

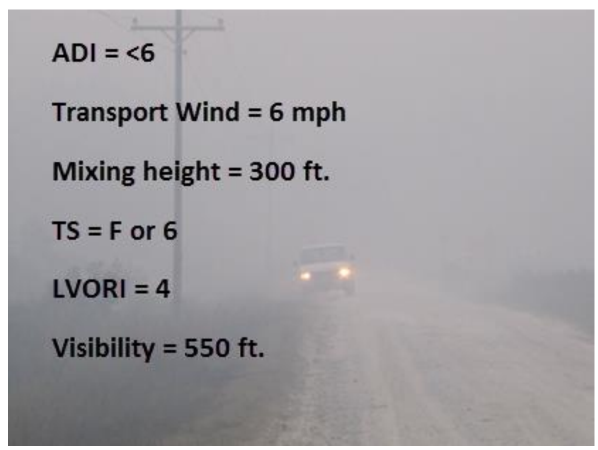
## THE ATMOSPHERIC DISPERSION INDEX (ADI)

- ***ADI is a numerical index estimating the lower part of the atmosphere's ability to disperse wildland smoke.***
- ***The Atmospheric Dispersion Index or ADI was originally developed to help assess the "diluting power" of the lower atmosphere for prescribed fires***.
- ***ADI depicts the effect of diurnal changes more clearly because it incorporates stability***.
- ***ADI takes into consideration the buoyancy of the atmosphere to disperse smoke.***

The Atmospheric Dispersion Index (ADI) is a numerical index estimating the lower part of the atmosphere's ability to disperse wildland smoke. Based on physical assumptions and mathematics, the index is expressed as a positive number. The higher the number the more effective the atmosphere is able to disperse pollutants. A doubling of ADI implies the effective doubling of the ability of the atmosphere to take on twice as much smoke.

The ADI was originally developed to help assess the "diluting power" of the lower atmosphere for prescribed fires. However, it is just as relevant for wildfires, as displayed forPains Bay Fire June 2$^{th}$, 2011. Currently the standard way to assess smoke dispersion conditions is to use the ventilation factor.

At sunrise, ADI is normally low. As the sun gets higher and induces more heating, the dispersion index will climb. At first, the amount of improvement will be minimal. About 3 or 4 hours after sunrise, the amount of improvement is usually significant. On average, the best dispersion will occur early to mid-afternoon. After this period, dispersion will start to degrade and towards sunset, it rapidly drops where vertical lifting is practically nonexistent. When trying to assess wildland smoke, the immediate lower part of the atmosphere is a major concern.



# Appendix C – Atmospheric Dispersion Index (ADI)

The dispersion index is conceptually similar to the ventilation factor, which is the product of mixing height and transport wind speed. The ventilation factor has its shortcomings, such as not clearly depicting the atmosphere's dispersion capacity under a low ventilation factor. Nor does it easily relate to dispersion under stable conditions. However, ADI depicts the effect of diurnal changes more clearly because it incorporates stability. The Pasquill–Gifford-Turner Stability Classification System combined with the ventilation factor makes the ADI a better estimator of the lower atmosphere's dispersion capacity. The index is optimized for burning activities within approximately 30 square mile area.The Stability Classification assigns one of seven classes using numbers 1 to 7 or letters A through G, respectively. Normally the atmosphere tends to be unstable (A, B, or C) or neutral (D) during the day and stable (E, F, or G) or neutral (D) at night. Also, neutral conditions are most likely during cloudy or windy regimes. Therefore, the ADI takes into consideration the buoyancy of the atmosphere to disperse smoke.

Therefore, ADI can serve as a guide to understanding how wildland smoke will disperse and whether mitigation actions are needed when dealing with surface smoke concentrations. Figure 6 is an interpretation of ADI values for day or night time hours. The ADI is not to be viewed as the one index that provides a simple clear answer to a complex issue concerning smoke dispersion. But is one tool that needs to be used in concert with Turner Stability, Low Visibility Occurrence Risk Index and surface weather variables. Surface weather intelligence (air temperature, relative humidity, wind speed) and cloud cover effect surface dispersion. It needs to be noted that if many fires occur in a given region, the lower atmosphere can be overloaded by the combined accumulated smoke.

The best fire weather intelligence comes from the NWS products PFW, AFM, Hourly Graphic Weather, and Weather Activity Planner only when they have been specifically enhanced for wildland smoke. These enhanced smoke products allow the use of the ADI and other indices, stability and weather elements in order to facilitate a comprehensive evaluation of surface dispersion conditions. The time windows for certain NWS Products permit an hourly evaluation of the lower atmosphere's diluting power.

- ***The ADI is not to be viewed as the one index that provides a simple clear answer to a complex issue concerning smoke dispersion. But is one tool that needs to be used in concert with Turner Stability, Low Visibility Occurrence Risk Index and surface weather variables.***
- ***The best fire weather intelligence comes from the NWS products PFW, AFM, Hourly Graphic Weather, and Weather Activity Planner only when they have been specifically enhanced for wildland smoke.***

# Appendix C – Atmospheric Dispersion Index (ADI)

| *ADI* | *Smoke Dispersion* | *Interpretation* | |
|---|---|---|---|
| | | *Daytime sunrise to sunset conditions* | *Nighttime sunset to sunrise conditions* |
| **>70** | **Very Good** | **Hazardous burning conditions. All prescribed or wild fires present control problems. Reassess decisions to burn.** | |
| **50 - 69** | **Good** | **Good burning weather conditions. Preferred range for prescribed burns.** | |
| **41 – 49** | **Fair to Good** | **Normal afternoon forest values. Good dispersion especially for burns <50 acres.** | |
| **21 – 40** | **Fair** | **Stagnant if wind speeds are low (<3 mph). Reassess decision to burn. Small acre burns successful with minimal ADI values ≥ 27.** | |
| **13 – 20** | **Poor to Fair** | **Do not burn within the WUI** | **Better than average nighttime values. Good nighttime dispersion w/ Turner Stability C (late into the night) or D.** |
| **6 – 12** | **Poor** | **Stagnant air daytime.** | **Near or average nighttime values. Very Poor nighttime dispersion w/ surface wind speed 5 - 8 Roadway visibility reduced or Fair 9 -12 mph and Turner Stability D, E, F, or G.** |
| **1 – 4** | **Very Poor** | **Stagnant air daytime very calm conditions.** | **Very frequent nighttime values. Stagnant air very little movement w/ surface wind speeds <3 mph or Very Poor with surface wind speeds 3-4, & Turner Stability E, F, or G.** |

Figure 6. An interpretation of ADI values for day or night time hours are presented in the above table. These values represent the combination of the original table developed by Lee Lavdas (1986), WUI table (2007) and nighttime ground fire observations from smoldering organic soil fires. Special Notes: 1) All referenced surface wind speeds in the table are NWS standard wind speeds which are observed at 10 meters. 2) Lavdas (1995) showed that:

a) ADI is strongly dependent on wind speed when ADI values are <20.
b) ADI values replaced by wind speed made very little change to NWS low visibility report (<1 mile) and Low Visibility Occurrence curves.
c) NWS low visibility report (<1 mile) are independent of ADI values <12.
d) NWS low visibility report when associated with LVORI, were critically dependent on very light wind speeds or ADI <3.
e) The frequency of smoke/fog related accidents picked up noticeably with RH >80% and ADI <16, and with the highest frequency of accidents occurring when RH >97% and ADI <3.

# Appendix C – Atmospheric Dispersion Index (ADI)

**References**

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# Appendix D – Low Visibility Occurrence Risk Index (LVORI)

## THE LOW VISIBILITY OCCURRENCE RISK INDEX (LVORI)

Wildland fires produce smoke that can contribute to reduced visibility over roadways with potentially tragic consequences. Prescribed burners and wildfire suppression personnel can minimize consequences by being aware of conditions that reduced roadway visibility and when present implement timely mitigation measures. This fire weather intelligence can be acquired from National Weather Service (NWS) through various products and needs to be incorporated into NWS WFO Annual Fire Weather Operating Plan.

### *WHAT IS "LVORI"?*

As noted by Lavdas (1996), LVORI is an index that numerically ranks, in relative terms, the likelihood of general weather conditions contributing to reduced visibility on roadways. The index, a function of the atmospheric dispersion index and relative humidity, ranks the relative likelihood of a fog and/or smoke-related accident in the southern coastal plain as is the case for the Pains Bay Fire 2011 in eastern NC.

Figure 7 Smoke from the Pains Bay Fire in 2011

The LVORI was developed through an analysis of National Weather Service climatological data (surface and upper air data) and accident data (1979 – 1981) supplied by the Florida Highway Patrol. Based on that data, the risk of smoke and fog reports at an accident site increases when relative humidity ≥80%, especially for very low Atmospheric Dispersion Index values (ADI is 1 – 12).

There are 10 LVORI categories; ranging from 1 (indicating the lowest probability of visibility restrictions) to 10 (indicating the highest probability of visibility restrictions). The LVORI and descriptions of the values are described in Table 1.

### *INTERPRETING "LVORI"*

Lavdas and Achtemeier (1995) state LVORI is an indicator only of relative risk, and ***should not be used as a hard estimate of absolute risk of hazardous visibility***. The index numbers should not be expected to predict specific visibility problems but are more an indicator that burn managers or wildfire personnel should be aware conditions are predicted that could lead to potential problems.

# Appendix D – Low Visibility Occurrence Risk Index (LVORI)

***LVORI is an indicator only of relative risk, and should not be used as a hard estimate of absolute risk of hazardous visibility*.**

When used for prescribed fire or wildfire operations, LVORI should be considered just another tool to evaluate smoke-related visibility hazards. LVORI can be used to: assess the degree of relative risk, how much risk is justified when considering the local climatology and what mitigating measures need to be in place. Keep in mind that LVORI frequencies may be highly variable with respect to location. Topographic influences such as drainages, bodies of water or open fields can serve as conduits or pools for wildland smoke.


Figure 8 Picture from the Dad Fire in eastern NC in 2012. Visibility reduced to 550 feet.

Based on Georgia and North Carolina operational experience caution needs to be exercised when one of the following situations exist:

1. LVORI is forecast at 8, 9, or 10;
2. Active smoke from stumps, logs, organic soil or deep duffs is present during the night; or
3. A roadway is located within 3 to 10 miles of the fire site with open fields, logging roads, or open streams that can provide an easy transit of smoke from the burn site to the roadway. Of course roadways within 3 miles of any type of fire site with persistent smoldering combustion through the night under favorable weather conditions would always be of concern.

LVORI of 6 or 7 should be treated with caution if there is active smoke produced during the night, and the fire site is within 10 miles of a roadway.
Florida offers the following guidance about LVORI and risks:

1. LVORI of 1: Ideally low risks of accidents on highways due to smoke and/or fog formation.
2. LVORI of 2 or 3: Relatively low risks of accidents on highways due to smoke and/or fog formation.
3. LVORI of 4, 5, or 6: Moderate risks of accidents on highways due to smoke and/or fog formation.
4. LVORI of 7, 8, 9, or 10: Particularly high risks of accidents on highways due to smoke and/or fog formation.

# Appendix D – Low Visibility Occurrence Risk Index (LVORI)

Wade and Mobley (2007) suggest that caution should be used when contemplating WUI (wildland-urban interface) burns with a LVORI of 5 or higher. They further recommend not conducting WUI burns when the LVORI is predicted to be 7 or higher unless the fire is completely mopped-up (out – no smokes) by dusk.

# Appendix D – Low Visibility Occurrence Risk Index (LVORI)

*USING "LVORI"*

- Use LVORI as a tool in evaluating the risk of reduced visibility associated with wildland fires.
  - ***Do not look at LVORI as the single indicator of whether fog will occur on a given night.***
  - ***Other parameters that should be considered in context with the LVORI include surface wind speeds, surface temperatures, relative humidity, stability class, atmospheric dispersion index, and amount of cloud cover.***
- As the LVORI increases (Category 5 and higher), the risk of reduced visibility due to fog and smoke increases.
  - Will active burning occur close to sundown? If so, the risk of nighttime smoke may be very high. Coupled with a high LVORI, the risk of reduced visibility increases even more.
- Consider the time of year when using LVORI. Remember the seasons that have a higher probability of fog occurring. Higher LVORI numbers during the "fog season" indicate a higher risk and mitigation measures may need beefing up.
- Will my wildland fire produce any nighttime smoke and is there a risk that smoke will impact a highway? What pre-cautionary steps are appropriate?
  - Contact local or state law enforcement (as well as emergency management) and notify them of potential smoke (conditions may be conducive to smoke/fog mix) on the roads; ask if they can check the road during early morning patrols (3 – 7 am)?
  - Can Federal Land Management Agency Law Enforcement assist with nighttime/early morning patrols of the area's roads?
  - Should Burn Boss or Operation Chief schedule road patrol by crew members?
  - Are warning signs placed so that motorists can be warned adequately?
  - If smoke/fog settles on the road, will the signs still be visible? Do the signs need to be relocated as visibility changes?
- Remember, even when fog is not predicted, nighttime smoke combined with high relative humidity can result in very poor visibility.

***Low Visibility Occurrence Risk Index (LVORI)*** is a numerical index to help Prescribed Fire or Wildfire personnel to assess the risk that smoke will reduce visibility on highways in the South or anywhere in the country where and when all the essential elements occur at the same time. The LVORI numerically ranks, in relative terms, the likelihood of general weather conditions contributing to reduced visibility on roadways. Local experience is important. In NC when the forecasts indicate a LVORI of 7 or higher, personnel may want to reconsider whether specific mitigation measures should be implemented (e.g., Super Fog Index, PB Piedmont model runs, highway signs, patrols to monitor highway visibility, mop-up of all residual smoke, etc.) or whether to carry out the planned burning operations during more favorable dispersion conditions. With ADI of 12 or less and relative humidity 80% and greater, the risks increase for reduced visibility.

# Appendix D – Low Visibility Occurrence Risk Index (LVORI)

| ***Low Visibility Occurrence Risk Index (10 point scale)<br>A function of relative humidity and Dispersion Index (Lavdas and Hauck, 1991)*** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Relative Humidity** | ATMOSPHERIC DISPERSION INDEN | | | | | | | | | | | |
| | **> 40** | **40-31** | **30-26** | **25-17** | **16-13** | **12-11** | **10-9** | **8-7** | **6-5** | **4-3** | **2** | **1** |
| **< 55** | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| **55-59** | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 |
| **60-64** | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 |
| **65-69** | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 |
| **70-74** | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 |
| **75-79** | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| **80-82** | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 6 |
| **83-85** | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 6 |
| **86-89** | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 6 | 6 | 6 |
| **89-91** | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 6 | 6 | 7 | 7 |
| **92-94** | 4 | 4 | 4 | 5 | 5 | 5 | 6 | 6 | 6 | 6 | 7 | 8 |
| **95-97** | 4 | 4 | 4 | 5 | 5 | 6 | 6 | 6 | 7 | 8 | 8 | 9 |
| **>97** | 4 | 4 | 4 | 5 | 5 | 7 | 8 | 8 | 9 | 9 | 10 | 10 |

Key to 10 point scale of proportions of smoke and/or fog accidents:

1. Lowest proportion of accidents with smoke and/or fog
2. Proportion of accidents not significantly higher (physical or statistical reasons for not including in class 1)
3. Higher proportion of accidents than class 1, by about 30 to 50 percent,
4. Significantly higher than class 1, by about a factor of 2
5. Significantly higher than class 1, by a factor of 3 to 10
6. Significantly higher than class 1, by a factor of 10 to 20
7. Significantly higher than class 1, by a factor of 20 to 40
8. Significantly higher than class 1, by a factor of 40 to 75
9. Significantly higher than class 1, by a factor of 75 to 125
10. Significantly higher than class 1, by about a factor of 150

# Appendix D – Low Visibility Occurrence Risk Index (LVORI)

**References**

Lavdas, L.G. 1996. Improving Control of Smoke From Prescribed Fire Using Low Visibility Occurrence Risk Index. USDA Forest Service, Southern Research Station, Dry Branch, GA (Publ. 1996 in the Southern Journal of Applied Forestry 20(1) 10-14.

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# Appendix E – Fog Potential Index

**Fog Potential Index – Coming Soon!**